The structure of nucleons and the description of the electromagnetic form factors

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Abstract

The comparison of different sets of PDFs structure functions with the description of the whole sets of experimental data of electromagnetic form factors of the proton and neutron is made in the frame work of our model [1] of t-dependence of generalized parton distributions (GPDs) and some other models. It is shown that despite a small difference of the description of the inelastic processes by the different sets of PDF there is an essentially large difference in the description of electromagnetic form factors of the nucleons.

1 Introduction

The new data of the TOTEM Collaboration show that none of the model predictions can describe the elastic cross sections at LHC. One of the main problem of the dynamical models is the form factors of the hadrons. In most part, the models are based on the assumption that the strong form factors correlate with the electromagnetic form factors. In practice, the models use some phenomenological forms of the form factors with the parameters determined by the fit of the experimental data. In some works [1], the idea was introduce that the strong form factors can be proportional to the matter distribution of the hadrons. In [2], the model was developed with the two forms of the form factors - one is the exact electromagnetic form factors and the other is proportional to the matter distribution of the hadron. Both form factors were obtained from the General Parton distributions (GPDs) which are based on the parton distributions (PDF) obtained from the data on the deep inelastic scattering. The model uses the old PDF obtained in [3]. In the framework of the model, a good description of the high energy of the proton-proton and proton-antiproton elastic scattering was obtained only with 3 high energy fitting parameters. There arrises a question: how the different PDF sets describe the electromagnetic form factor of the hadrons. For that, we make a simultaneous fit of all available experimental data on the proton and neutron electromagnetic form factors using the different PDF sets with the some model of the t-dependence of the GPDs.

2 The description of the electromagnetic form factors

The electromagnetic form factors can be represented as the first moments of GPDs

$$F_1^q(t) = \int_0^1 dx\ \mathcal{H}^q(x,t); \quad F_2^q(t) = \int_0^1 dx\ \mathcal{E}^q(x,t), \tag{1}$$

following from the sum rules [4].

Recently, there were many different proposals for the t dependence of GPDs. We introduced a simple form for this t-dependence [5] based on the original Gaussian form corresponding to that of the wave function of the hadron. It satisfies the conditions of non-factorization, introduced by Radyushkin, and the Burkhardt condition on the power of $(1-x)^n$ in the exponential form of the t-dependence. With this simple form we obtained a good description of the proton electromagnetic Sachs form factors. Using the isotopic invariance we obtained good description of the neutron Sachs form factors without changing any parameters [5].

Let us modify the original Gaussian ansatz and choose the t-dependence of GPDs in the form

$$\begin{aligned} \mathcal{H}^q(x,t) \ = \ & (\frac{2}{3}\ q_u\ exp(2\alpha_1 \frac{(1-x)^{p_1}}{(x_0+x)^{p_2}} t) \\ & -\frac{1}{3}\ q_d\ exp(2\alpha_1 [\frac{(1-x)^{p_1 k_d}}{(x_0+x)^{p_2}} t) + d\ x(1-x)]\ t); \end{aligned} \tag{2}$$

$$\begin{aligned} \mathcal{E}^q(x,t) \ & = (\frac{1.673}{uN}\frac{2}{3}\ q_u (1-x)^n)\ exp(2\alpha_1 \frac{(1.-x)^{p_1}}{(x_0+x)^{p_2}} t) \\ & -\frac{2.033}{dN}\frac{1}{3}\ q_d\ (1-x)^m) exp(2\alpha_1 [\frac{(1-x)^{p_1 k_d}}{(x_0+x)^{p_2}} t) + d\ x(1-x)]\ t). \end{aligned} \tag{3}$$

The parameters k_d and d reflect the possible flower dependence of GPDs.

We analyzed four cases: a) with minimum free parameters and flower independence (basic variant), as was made in [5]; b) k is taken as a free parameter; c) p_1 and k are taken as free parameters; d) p_1, k and d are taken as free parameters (maximum flower dependent). A further increase in the number of the free parameters does not give essentially improving of χ^2. It leads only to the increasing in the size of the errors of the parameters. PDF

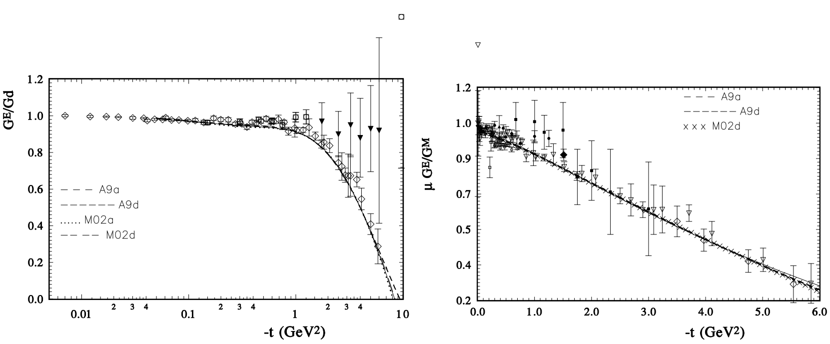

Figure 1: (left)The proton G_E/Gd; (right) $\mu G_e/G_M(t)$.

sets were taken as 15 variants in different works with taking into account the leading order (LO), next leading order (NLO) and next-next leading order (NNLO). The experimental data on the electromagnetic form factors were represented by 508 points in the maximum and 415 points in the minimum variants. The best description was obtained with the PDF sets [6]. In this case, all 4 variants of the t-dependence gave a very close size of χ^2. Also, we obtained a good description with the PDF sets [7, 8] and on the third place we can put the variants with the PDF sets [3, 9]. It is to be noted that the different PDF sets give similar descriptions of the proton form factors and a large difference in the description of the neutron form factors (see Fig.1 and Fig.2). Just the neutron data in most part lead to the essentially better description of the polarization data on the electromagnetic form factors.

3 Conclusions

We examined some new forms of the momentum transfer dependence of the GPDs with the different sets of the PDFs. It was found that the new form only slightly differs from the simplest t-dependence of the GPDs proposed in [5]. Contrary to work [10], we found a small flavor dependence of the u and d components of the GPDs. We found that maximum 5 free parameters are required for a simultaneous description of the electromagnetic form factors of the proton and neutron. It was shown that the different PDF sets lead to the essentially different descriptions of the electromagnetic form factors. The best description was obtained with the set of PDFs [6]. In the final analysis we found that a simultaneously description of the proton and neutron electromagnetic form factors leads to the "polarization" case of the t-dependence of the form factors (Fig. 1b). The description of the proton electromag-

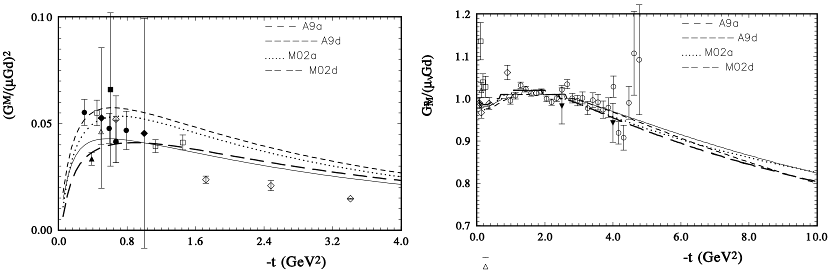

Figure 2: Neutron $[G_M/(\mu Gd)]^2$ (left - small t; (right) - large t).

netic form factors with different PDF sets has a large difference only at high t. The largest difference comes from the description of the electromagnetic form factors of the neutron (see Fig.2).

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